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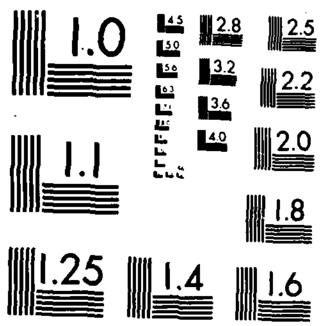

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Applying Activation Theory for Modeling Task Interference in Dual-Task Situations

David Navon

June 1986

Final Report

Contract N00014-85-K-0313

Institute for Cognitive Science
University of California, San Diego
La Jolla, California 92093

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This document constitutes a final report for contract N00014-85-K-0313, NR 667-546, from the Office of Naval Research. The purpose of this one-year contract was to attempt to model the sources of task interference other than competition for processing resources. First, a general theory of attention was developed. The theory posits parallel computations by entities called modules, with little competition for common resources. Attention is assumed to control only the communication among modules. It is shown that the attentional mechanism is a vehicle for achieving selectivity, but is less fit for coping with multiple goals. Second, task interference of a type that is called crosstalk was computer-simulated on a parallel distributed processing (PDP) network. Several interesting results emerge out of the simulation. Third, the role of conflict between outcomes of processes in producing task interference was studied experimentally. Subjects searched for different sorts of targets, each assigned to a different attentional channel. Confusability between channels and congruence of responses to them were found to be potent determinants of task interference. We suggest that potential sources of outcome conflict may contribute to dual-task interference and argue that a great deal of the residual interference might result from other sorts of outcome conflict.

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Applying Activation Theory for Modeling Task Interference in Dual-Task Situations: A Final Report

DAVID NAVON

A prevalent approach to optimization of the environment of an operator of a complex system is to characterize the situation as a problem of demand and supply: The system imposes some load, and the operator offers his/her mental resources to meet the load. Since the operator's resources are limited, a problem of scarcity might arise.

This conceptual approach underlies a vast amount of research in the area, both basic and applied. Researchers differ mostly on whether they believe that the supply of resources is fixed or demand-dependent (Kahneman, 1973), that there is one pool of resources or a number of them (Navon & Gopher, 1979; Norman & Bobrow, 1975; Wickens, 1980), and that *all* mental activities require resources or just *some* of them (Neisser, 1967; Posner, 1978; Schneider & Shiffrin, 1977). But the implicit postulate is that the problem is basically an economic one, and that as such it may be solved either by lowering the demand or by increasing the supply, e.g., by designing a less demanding information display or by training operators to mobilize more resources or to manipulate them more efficiently, etc.

Much has been hoped to be gained by this approach, but what has been actually gained is considerably less than that (see Navon, 1984, 1985). Since the framework of resources theory, despite its intuitive appeal, has not yet succeeded in imposing conceptual organization on behavioral phenomena in the field of human performance, let alone in predicting them, alternative approaches ought to be considered. A prominent alternative is a theory that ascribes task interference to some outputs or side effects generated as a product of the processing of a task, that are harmful to the processing of the other task. To take a physical analogy, stimultaneous phone calls will interfere with each other even when their number does not exceed the number of available lines if there is some crosstalk among parallel lines due to electrical induction. Alas, this obvious theoretical possibility is not very illuminating in itself when one comes to explain or predict task-interference. The objective of this one-year project was to attempt to model the sources of task interference. We proceeded along three avenues: conceptual, computational, and experimental.

Visibility or Disability

The first line of effort was invested in trying to construct a framework of a theory of attention that posits parallel computations with little competition for common resources. The product is described in a report entitled "Visibility or Disability: Notes on Attention" (Navon, 1986).

In the report, the mind is likened to a set of mental entities called *modules* that function much like people do in their community: They may be active in parallel, they specialize in some computation, and they may be called to apply their specialized ability for some goal that is recognized as important and that typically requires the cooperation of a number of processes.

A critical requirement for attaining the desired cooperation is *communication*. Communication is required for two major objectives: (a) to announce current goals and (b) to transfer or exchange information pertinent for accomplishing the goals. Thus, goals are more likely to be attained when they, as well as the processing modules involved in accomplishing them, can adequately communicate among themselves. However, sufficien communication is not guaranteed for all of the goals the environment might suggest at any particular moment. This constraint dictates two basic facts of life in the community of processing modules comprising the mind:

- Goals compete for communication, and attention is called forth to resolve the conflict.
- Goals can survive better when they secure for themselves some communication through learning.

In the report we concentrate on the role of attention in managing communication in a multiple-goal environment.

Modules operate within, or deliver their products to, media which may be called *structures*. When modules operate concurrently within the same structure, *outcome conflict* may emerge; that is, the operation of a module may generate some outcome—output or side effect—that interferes with the operation of another module (see Navon, 1985). Processing modules are assumed to be active as long as their trigger is present and as long as their stopping state is not. Activation is, thus, externally driven and uncontrollable.

Attention is assumed to make the agenda of the mind goal-compatable. But it makes goal-compatability without any control over the activation of modules. What attention does control is the communication among modules. It exerts attentional emphasis by bringing the output of a to-be-attended module to the information of a maximal number of other modules, while limiting the ability of de-emphasized modules to propagate their output. This is achieved by a mechanism called *decoupling* that controls the connections among modules.

The control of decoupling that is required for attentional emphasis is associated with what is phenomenally felt as effort. Since effort is aversive, motivation is needed to override the aversion, so that effort is exerted. The mechanism of decoupling is a vehicle for achieving selectivity. It was not designed and is not fit for coping with multiple goals at the same time. The reason is that the very same factors that make decoupling functional for emphasizing modules relevant for a single goal fail the system when it tries to share emphasis between two goals. If attention secures great "publicity" to just one set of modules, then anything within the public communication devices is relevant to the modules. However, when the public forum accommodates two sets of users, confusion is very likely, and it can be avoided only at the cost of large delays. This is a sort of outcome conflict between tasks. The more complex the tasks—namely the more modules are involved in attaining one goal and the more output they generate—the more detrimental the effect of sharing attention. That is, decoupling is required for divided attention between unpracticed tasks, but is very inefficient. The more complex a task, the more harmful the consequences of divided attention. The report sketches an entire system that is based on these principles. The architecture of the control over decoupling and the strategies used to cope with various situations are elaborated on.

Simulating Outcome Conflict

Another avenue of research was to try to specify the model of tsk interference sufficiently to simulate it on a computer. Some results are described in a technical report entitled "Serial Order: A Parallel Distributed Processing Approach" (Jordan, 1986).

Decoupling theory, described above suggests that the main determinant of task interference is outcome conflict arising in common structures. Outcome conflict is, of course, a very general concept, and it may stem from different sources in different systems. In his paper, Jordan presents an attempt to

conceptualize a type of outcome conflict referred to as *crosstalk* within a parallel distributed processing network (see, e.g., Rumelhart & McClelland, 1986, for discussion of these networks).

It is shown that outcome conflict is greater the higher the similarity of concurrent tasks, that it can be eliminated by practice, but that task similarity and amount of practice interact. It is also shown that outcome conflict is greater the more prior learning on *other* tasks has been stored in the system. It was also demonstrated that outcome conflict can be avoided by training the two tasks as a single combined whole, but that this has a cost in terms of single-task performance.

The Role of Outcome Conflict

The third avenue of research was experimental. The view we developed states that the major source of task interference is outcome conflict. We set out to demonstrate experimentally the role of outcome conflict in producing task interference as well as to explore the various sources of outcome conflict. The first results are described in a technical report entitled "The Role of Outcome Conflict in Dual-Task Interference" (Navon & Miller, 1986).

We used a paradigm in which subjects searched for different sorts of targets, each assigned to a different attentional channel. Stimuli were visually presented in a cross array, the limbs of which were designated as the channels. Subjects were to respond to the presence or absence of targets at a given channel by alternative responses of a specific effector (say, the middle and index fingers of the right hand). To explore the contribution of outcome conflict to task interference, we manipulated the relatedness of the search tasks assigned to the two channels.

In Experiment 1, subjects searched concurrently for names of boys in one channel and names of cities in another channel. Responses were significantly delayed when a nontarget on one channel belonged to, or was even just related to (namely, a name of a girl or of a state) the category designated as the target for the other channel. No comparable effects were found when the subjects had to focus on just one task. Thus, the difficulty of the individual tasks is not the only determinant of how much they will interfere when combined, and there must be substantial interactions between processes carrying out the two tasks.

In Experiment 2, subjects searched one channel for specific target letters and another channel for specific target digits. The nontargets in a channel were either from the same alphanumeric category as the targets for that channel or from the opposite category (i.e., the category of the targets for the other channel). It was found that although between-category search was more efficient than within-category search in single tasks, it was less efficient in dual tasks. Thus, there appear to be significant task interactions due to the confusability emerging when the nontargets of one task belong to the same category as the targets of the concurrent taks. In addition, the congruence of target presence or absence on the two channels was found to have a sizeable effect.

On the basis of the results we suggest four possible sources of outcome conflict that may contribute to dual-task interference: the effects of off-channel targets and off-channel associates on responses to the other channel, effects that we ascribe to some perceptual conflict; the effects of these items on the response to the channel on which they appeared (these effects are called S-R mapping conflicts); an effect on the strategy subjects use when they anticipate possible outcome conflict; and an effect of target presence/absence congruence, that we denoted a cross-response conflict. Taken together, those effects account for a large part of the extra difficulty of dual-task performance. We argue that a great deal of the residual interference between tasks might result from other sorts of outcome conflict that we have not tapped with our manipulations.

Status of Project

We have started working in three avenues and work is still in progress. The technical reports summarize the achievement so far. In view of the fact that the contact is limited, we feel that what has been already done represents a good progress. We hope to be able to develop the theory and obtain more pertinent data. First, we hope to account for a broad set of phenomena such as dual-task interference, dual-task facilitation, Yerkes-Dodson law, attentional strategies (relaxed/ effortful) and their interaction with types of task, subjective feeling of effort, the relationship between effort and awareness, and even states of consciousness (dream, meditation, and hypnosis). The accounts must have little in common with other prevalent views. Second, we intend to explore the various sources of outcome conflict, the plausibility of reducing task interference by co- 'ling outcome conflict, and the relative importance of outcome conflict as a determinant of task interference.

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